Review of Early Mobilization of Muscle, Tendon, and Ligament After Injury in Equine Rehabilitation

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Mobilization for most injuries and postoperatives can begin within 3 days if careful protocols are followed. For severe ligament and tendon injuries, mobilization can begin at 3 wk, with initiation of low-level mobilization at 3 days. Early mobilization should include weight-bearing activities, strengthening, and flexibility, whereas stall rest alone should be used as infrequently as possible. Authors' addresses: EquiNew, 8139 900th Street, River Falls, Wisconsin 54022 (Schils); and Anoka Equine Clinic, 16445 70th Street NE, Elk River, Minnesota 55330 (Turner); e-mail: sbschils @EquiNew.com. © 2010 AAEP.

1. Introduction

Research in human rehabilitation has shown that even in the acute phases of injury, early mobilization can be used successfully to produce better quality healing for muscles, tendons, and ligaments.[1,2] Immobilization is now minimally used, and protocols have changed from long, complete immobilization to early, controlled mobilization immediately after trauma. During rehabilitation, active joint motion and weight-bearing activities are recommended earlier than ever before. Continuous passive motion or range of motion exercises are advised immediately after surgery or injury in most rehabilitation protocols.[2–4]

Several factors explain the benefits of early mobilization for both injury and postoperative healing. Compared with immobilization, mobilization will:

1. Increase blood and lymphatic flow to aid in healing.[4–7]
2. Produce tension to stimulate tissue repair for faster healing.[7–9]
3. Produce tension to improve tissue alignment during healing.[10–12]
4. Limit the extent of connective tissue fibrosis.[9–11,13,14]
5. Preserve coordination caused by the neuromuscular activation from exercise.[15,16]
6. Preserve range of motion to avoid or minimize joint fibrosis.[9–11]
7. Maintain proprioceptive functions, if a variety of stimuli are used.[13–14]
8. Produce a quicker recovery and return to full activity.[2,4,11–13]

Immobilization may be necessary with wounds, fractures, and severe ruptures so that enough mechanical strength can develop before mobilization. However, muscle, tendon, and ligament tissues require regular, appropriate loading during healing to maintain their strength and function.[2,4,12,17–19] The concern that early mobilization may affect the quality of long-term healing and result in more frequent reinjuries has not been substantiated when the appropriate mobilization process is used. Re-

NOTES

MUSCLE REHABILITATION PROTOCOL					
	Onset of injury	Day 3	Week 1	Week 2	Week 3
Grade 1	IC* and F	F	F	S and F	S and F
Grade 2	IC and F	F	S and F	S and F	S and F
Grade 3	RIC*	S (light)	S and F (light)	S and F	S and F
TENDON/ LIGAMENT REHABILITATION PROTOCOL					
	Onset of injury	Day 3	Week 1	Week 2	Week 3
Grade 1	IC and F	F	F	S and F	S and F
Grade 2	IC and F	F	S and F	S and F	S and F
Grade 3	RIC	S (light)	S and F (light)	S and F (light)	S and F
F = Flexibility exercises S = Strengthening exercises *IC = Ice, Compression *RIC = Rest, Ice, Compression					

Fig. 1. Early mobilization techniques for muscle, tendon, and ligament.

search has shown that correct early mobilization is a better alternative to immobilization and does not lead to a higher reinjury rate.[20]

Horses pose specific problems, and the direct transfer of rehabilitation techniques used by human practitioners is difficult. Early mobilization of a limb that is painful to a horse will not be easy, and the use of tranquilizers is not widely recommended in rehabilitation. Therefore, specialized mobilization techniques and modalities that are comfortable to the horse are necessary.[21–25]

This paper presents information on the use of early mobilization in the human population and offers suggestions of how this information may be extrapolated to equine practice.

2. Early Mobilization Versus Immobilization

In 2001, a systematic review of human subjects found that functional exercises were more effective than immobilization. Early mobilization helped return the patients more quickly to physical activity, reduce persistent swelling, restore stability, restore range of motion, and improve patient satisfaction with the rehabilitation outcome.[26]

Current rehabilitation practices replace immobilization with specific exercises to improve muscle and joint movement and reduce pain. These exercises focus on low loads and multiple repetitions several times a day, emphasizing a balance between strength and flexibility.[27] Figure 1 outlines the progression of techniques in human rehabilitation and approximately when each exercise should begin.

Positive results with the use of mobilization have been found for ankle ligament ruptures and instability,[28–31] knee ligament injury,[32,33] articular cartilage injury,[34] cubital tunnel release surgery,[35] distal radius fracture,[3] complete Achilles tendon rupture,[36,37] and elbow and shoulder dislocation.[1,38] For example, one study of ankle sprains found that 54% of the mobilized group returned to work in 1 wk compared with 13% of the immobilized group. In

addition, the mobilized group had less pain than the immobilized group (57% vs. 87%).[29]

The effects of 7 wk of cast immobilization have been studied on the healthy forelimbs of horses. Even after 8 wk of forced exercise after cast removal, the limbs did not return to their pre-immobilized musculoskeletal state.[39,40] When bone mineralization and strength were evaluated after 8 wk of casting, improvements were slow but accelerated after the horses returned to free exercise.[41] In addition, immobilization from 30 days of casting showed a decrease in the structural components of bone and articular cartilage in the casted limb. The uncasted limb showed improved integrity during the trial, probably because of increased weight-bearing activity.[42]

Conversely, if mobilization happens too early after injury, the repair process may be inhibited. Inflammation is not always bad, and phagocytosis has been shown to be necessary to stimulate healing.[43,44] In addition, overloading during the early stages of rehabilitation can be detrimental and may lead to increased connective tissue formation.[6,17] The appropriate amount of mobilization is necessary so that the healing process is stimulated but not overstressed.

Some longitudinal studies comparing the quality of healing between early mobilization and immobilization did not show a long-term difference. However, the authors stated that the early mobilization group had faster recovery rates and were more satisfied with the rehabilitation, even if the physiological outcome was similar. Because of these factors, the authors concluded that mobilization should still be recommended over immobilization.[29,45]

3. Muscle Rehabilitation

Muscle injury is most often attributed to three factors: inadequate muscle length or strength, muscle fatigue, and inadequate muscle skills. Most muscle problems in humans involve two-joint muscles, probably because of the synchronization of contraction and relaxation.[46,47]

Skeletal muscle can change relatively quickly in its composition and functional characteristics to adapt to different types and levels of stresses.[1,48] Unfortunately, this ability to quickly adjust can be positive or negative during recovery from injury. Immobilization can produce significant changes at the muscular level in a short period of time. Healthy human subjects that were placed in a fiberglass cast had an approximately 50% decrease in the strength of their knees in 3–4 wk.[49,50]

Much of the current research has found that mobilization should be started as soon as possible to properly align the regenerating muscle fibers, limit the extent of connective tissue fibrosis, regain flexibility, and prevent further injury and inflammation.[10,11] The lack of weight-bearing activity reduces the rate and quality of muscle healing,[7,17]
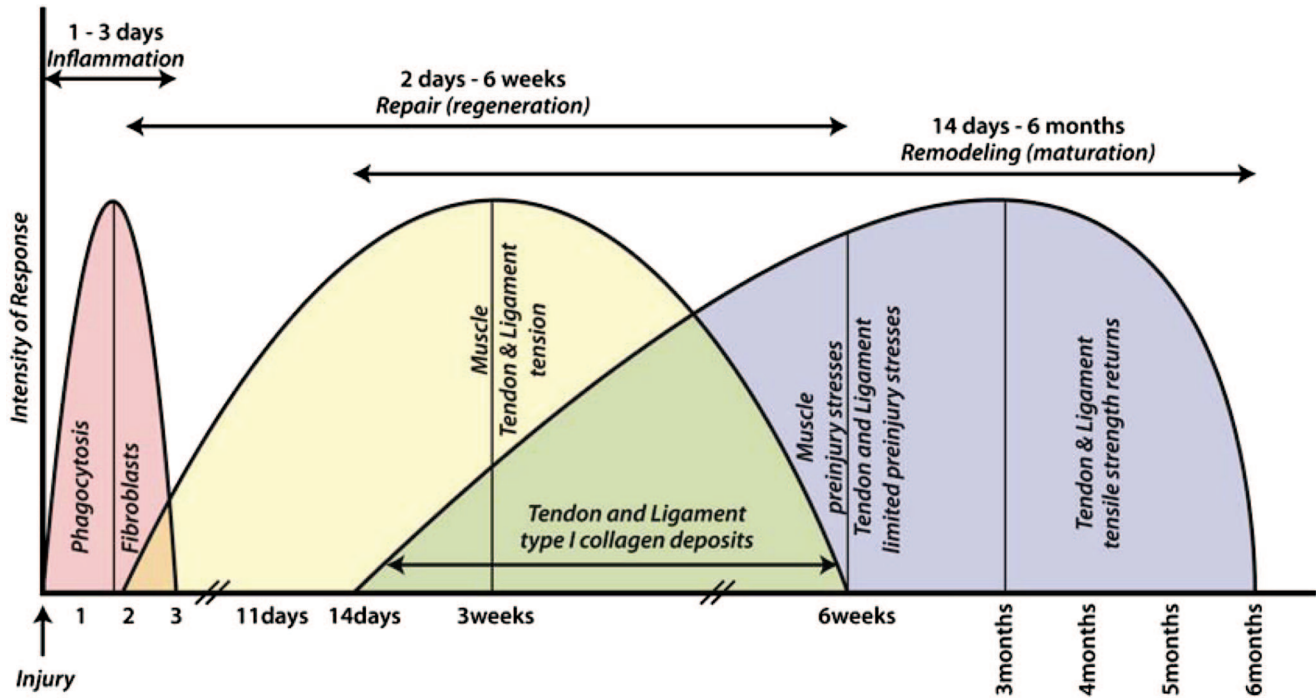
Fig. 2. Muscle, tendon, and ligament phases of healing.

and even in cases of severe injury, active mobilization is begun within the first week.[11]

Human studies have found that 4–6 wk of bed rest resulted in a decrease of up to 40% of muscle strength, and after 6 mo of exercise, losses in bone mass still had not fully recovered.[15] Another study found that after 3 days of bed rest, peak-power output declined 14.3% in endurance athletes and 10% in strength-trained athletes.[51]

As a consequence of immobilization, the recovery of strength and muscle mass can take years. In longitudinal studies of up to 5 yr, the immobilized group showed a greater reduction in strength and muscle mass.[27,52–55] In addition, certain muscles tend to atrophy more than others during immobilization. For example, the wasting of the quadriceps is more common than the atrophy of the hamstring muscles.[1,52,56]

Immobilization also causes neural changes that affect the function of the muscle. Studies have found that, after 1–4 mo of immobilization, there was a reduced number of functional motor units and a decrease in reflex potential.[16]

The activation of both synergistic and antagonist muscles is also important to quality healing. Without that activation, maturation of the injured muscle does not occur because of the lack of contractile activity.[7] When rehabilitation of acute hamstring strains emphasized isolated stretching and strengthening of only that muscle group, 54% of the athletes reinjured. When hamstring-specific exercises were combined with pelvis/trunk muscle exercises, the reinjury rate was zero.[10]

Therefore, when should early mobilization begin? Most practitioners agree that, between 1 and 3 days after the initial inflammation period is over, mobilization exercises can begin. In less severe injuries, mobilization can occur immediately after trauma. After approximately 6–8 wk, the new muscle tissue can accept near pre-injury stress, and protection is no longer needed (Fig. 2).[6]

4. Tendon and Ligament Rehabilitation

There are differences between ligament and tendon structures, but in rehabilitation, they are viewed in similar ways.[13,57] In general, ligaments and tendons are soft connective tissues that stabilize and guide the motion of joints and transmit forces from bone to bone and muscle to bone.[4]

Ligament and tendon injuries typically occur with pathological rotation, overloading, or excessive, repetitive loading.[58,59] In addition, injuries almost always affect several structural components, rather than just one component.[60]

Immediately after injury, the ligament or tendon is filled with inflammatory cells. Within 24 h, phagocytosis is removing debris and necrotic cells. At about day 2, the macrophages are gradually replaced by fibroblasts, and the lay down of type III collagen scar tissue begins. Between 3 and 6 wk, the turnover begins, and type I collagen begins to predominate.[61] At 6 wk, the tendons and ligaments can withstand pre-injury stresses but not at pre-injury repetitions. This level of work is recommended because of the fact that human tendons

during exercise have been found to have stresses of 25–33% of their maximum strength (Table 2).[62]

In animal models, surgeries and induced injuries were performed on Achilles tendons and medial collateral ligaments (MCL). When early mobilization was compared with immobilization, strength was significantly improved,[63–66] overall healing was better,[67] there was better orientation and organization of tendon collagen,[68] and there was an increase in collagen and extracellular matrix synthesis.[9] Ultrasound comparisons of knee ligaments found larger fiber bundles caused by increased type 1 collagen content when comparing mobilized versus immobilized tissues.[69,70] Early mobilization after Achilles tendon surgery is now commonly recommended.[71,72]

Studies have shown the benefits of mobilization compared with casting of tendon and ligament injuries. Early mobilization produced improvements in the tendon collagen deposition (60%), increased maximum load potential (20%), and increased maximum stress potential (21%) compared with immobilization.[73]

Immobilization between 8 and 12 wk produced a 39% loss of ligament tensile strength[74] and a 30% reduction in type 1 collagen mass.[75] With immobilization, ligament insertion sites were weakened, producing capsular changes that led to joint stiffness.[57,61]

Results of the mobilization of MCL surgeries have shown that 12–18 wk of exercise training is necessary before a return to normal tensile strength occurs (Fig. 2).[65,66] If immobilization is used, strength can take from 9 mo to 1 yr to return.[66,74] Early exercise training after injury led to a 98% return to the properties of a canine collateral ligament compared with a 54% failure rate for those dogs immobilized for 6 wk after injury.[65]

Reinjury occurrence was studied where early mobilization after surgery was used. The patients from 64 Achilles tendon ruptures were placed in moveable braces for 4–6 wk followed by 10 wk of exercises. Early mobilization reduced the range of motion loss, increased blood supply, and reduced the degree of muscle atrophy. No reruptures occurred to the subjects participating in this study.[76]

However, it should not be implied that tendon or ligaments will return to a pre-injury state through the process of correct rehabilitation. Early mobilization has been shown to improve healing compared with immobilization, but it does not necessarily return the tissues to pre-injury status.[56]

Conversely, aggressive mobilization during the first 3 wk may be detrimental to collagen orientation, leading to gap formation and/or repair failure.[77,78] Studies found that for severe ligament damage, collagen remodeling is best with site immobilization for up to 3 wk followed by mobilization (Fig. 2).[79] In addition, some research has shown that during nerve regeneration, early mobilization

may delay revascularization and encourage more scar formation.[80]

When should mobilization occur for tendon and ligament damage? With grade 1 and 2 injuries, early mobilization can begin within 3 days. With grade 3 injuries, active mobilization should occur after 3 wk, although passive mobilization can begin within 3 days after injury. The previous standard of 6 wk of immobilization is not frequently recommended (Fig. 1).[13]

It is useful to note that, in human athletes, grade 1 and 2 injuries almost always have some pain after the initial trauma. In grade 2 injuries, the athlete typically cannot continue to perform. In grade 3 ruptures, there is severe pain when the trauma occurs, but there may be little pain soon after. Many times, because there is no severe pain, the athlete will then continue to perform, which leads to even more severe damage.[13]

The majority of the past research on tendon and ligament healing has focused on collagen type. As research progresses, the understanding of the role of the proteoglycan matrix and other non-collagenous cells in healing will further assist the development of rehabilitation techniques.[81–84]

5. What Type of Mobilization Program Should Be Used?

The type of mobilization exercises used depends on the injury. In most rehabilitation protocols, continuous passive motion or range of motion exercises are performed within the first day after injury or surgery. Ice, compression, elevation, weight-bearing activities, and electrical stimulation are also started immediately, and the intensity and repetition of these exercises increases as the rehabilitation program progresses. In addition, exercises to address the complimentary musculoskeletal system are also introduced, especially if distinct asymmetries are noted.[85]

Generally, with severe injuries, stabilization is the first priority, and this is obtained through muscle strengthening. However, if the strengthening phase lasts too long, flexibility can be hampered. Flexibility exercises are the most commonly overlooked part of the rehabilitation process and are incorrectly thought to be secondary in importance to strengthening (Fig. 1).

When atrophy is present, strengthening of the muscles is primary. Slow-twitch muscle fiber tends to atrophy faster than fast-twitch fibers, and the level of connective tissue is increased in atrophied muscle.[52] Research has shown that after joint damage, there may be selective inhibition of motor units, which could explain why atrophy many times occurs after joint injury.[86]

Flexibility exercises should be incorporated into the mobilization programs as early as possible.[87–89] Many times, the flexibility exercises are much more difficult for the client to perform, but the addition of

flexibility during almost all stages of rehabilitation must be emphasized.[90,91]

To heal injuries during early mobilization and prevent reinjury, flexibility training is extensively used.[92–95] Controlled stretching can increase collagen synthesis and improve fiber alignment, leading to improved strength.[4] However, too much flexibility can also prove detrimental, and both hyper- and hypoflexibility were found to increase injury in one study.[96]

Range of motion is related to the level of flexibility, and normal ranges of motion in most joints have been established for humans. These ranges are used to determine the flexibility exercises needed as well as guide the progress of the rehabilitation program.[97–99]

A direct relationship between the level of pain and the level of inflexibility has not been found. Muscle inflexibility may be as severe in the later pain-free stages of rehabilitation as it is in the earlier, more painful stages of injury. Therefore, pain is not always the best guide in determining muscle-flexion limitations.[100,101] In addition, a very small amount of joint effusion can reduce muscle flexion, and therefore, joint stiffness is typically related to the level of flexibility.[102,103]

The load applied during mobilization is specific to the injury and the species, and a high stretching force during rehabilitation is not necessarily better. Suture type in postoperative rehabilitation has also been studied to determine the forces that the sutures can withstand.[78,104] Low forces (5 N) have been found to produce as much improvement in strength and reduction in stiffness as higher forces (17N) when used on canine flexor tendons.[78] In addition, tendons that are under high tensile loads should not be stressed during flexion to the level of tendons at lower tensile loads.

In general, the forces used in early mobilization will be those used to perform weight-bearing activities. In addition, site-specific and site-complimentary exercises should include flexion and extension.[85]

6. Summary

Early mobilization techniques for muscle, tendon, and ligament injuries have been used for over 30 yr to improve the quality of healing and decrease rehabilitation time. During this time, an understanding of the response of tissues to mobilization has led to a refinement of rehabilitation techniques. In clinical practice, immobilization is avoided if at all possible.[27,86]

Early mobilization programs must be specifically designed for each joint and each type of injury. Strength and flexibility exercises are combined at the proper levels and times to maximize the healing process. Site-specific as well as site-complimentary exercises should both be included in the rehabilitation protocol, and too much stress can harm the repair process as much as complete immobility.

Balance is the key to quality rehabilitation, and practitioners knowledgeable in physical therapy can be helpful in establishing the appropriate program.[20] Poor-quality rehabilitation is a vicious cycle of immobilization, muscle stiffness, joint stiffness, and joint damage, leading to muscle wasting.[4,27,86]

The evidence is compelling enough that guidelines extrapolated from human rehabilitation for the use of early mobilization in equine practice may be productive. Protocols will need to be refined from the large body of equine anecdotal information that exists, and human techniques will need to be modified to suit the specific needs of equine rehabilitation (Fig. 1).[85]

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